Chapter

Role of Microbial Enriched Vermicompost in Plant-Parasitic Nematode Management

Sunil Kumar, Ranjit Kumar and Pankaj Sood

Abstract

Earthworm causes increase in availability of soil organic matter through degradation of dead matters by microbes, leaf litter and porocity of soil. Vermicompost is a non-thermophilic biodegradation process of waste organic material through the action of microorganism with earthworm. Vermicompost is rich in many nutrients including calcium, nitrates, phosphorus and soluble potassium, which are essentially required for plant growth. Different plant growth hormones like gibberellins, auxins and cytokinins are present in vermicompost, which has microbial origin. Nematodes are mostly small, colorless and microscopic organisms which remain under soil, fresh or marine water, plants or animals, and act as parasite in different conditions, while very few have direct effect on human. The nematodes which are parasitic on plants use plant tissues as their food. They have well developed spearing device, like a hypodermic needle called stylet. It is used to penetrate host cell membrane. Management of plant-parasitic-nematodes therefore is necessary and several means are adopted. Of which, use of bio-chemicals and organic compost have shown encouraging results and proved to be potential in suppressing the nematode population. Vermicompost plays an important role of soil fortification on growth characteristics, such as length, weight, root, shoot branches, number of leaves and metabolism of host plant against nematode infection. Vermicompost fortified plants showed increment in sugar, protein and lipid over untreated control. Increment of these metabolites helps treated plants to metabolically cope up the infection and promotes excessive plant growth. The vermicompost caused the mortality of nematodes by the release of nematicidal substances such as hydrogen sulfate, ammonia, and nitrite apart from promotion of the growth of nematode predatory fungi that attack their cysts. It favours rhizobacteria which produce toxic enzymes and toxins; or indirectly favors population of nematophagous microorganisms, bacteria, and fungi, which serve as food for predatory or omnivorous nematodes, or arthropods such as mites, which are selectively opposed to plant-parasitic nematodes.

Keywords: Vermicompost, nematode, nematophagous, *Meloidogynae*

1. Introduction

The term vermicompost is derived from a latin word “vermes” meaning “worms” and the process of composting of organic material using earthworms is known as vermicomposting. Earthworms directly influences the microbial community of soil and it maintains normal chemical and physical properties ofsoil, due to which it is popularly called the "farmer's friend".

Earthworm causes increase in availability of soil organic matter through degradation of dead matters by microbes, leaf litter and porocity of soil. Vermicompost is a non-thermophilic biodegradation process of waste organic material through the action of microorganism with earthworm. The product produced through vermicompost is highly fertile, very finesoilparticles with marked porosity, adequate aeration, low C: N ratios and high water-holding capacity [1]. The termed "drilosphere" is coined for microflora and microfaunain soil influenced by earthworms [2].

Due to decrease in land availability for cultivation, waste disposal and exponential increase in human population there is urgent need to improve crop production and waste disposal mechanism. Crop intensification has led to huge use of chemical fertilizers and pesticides which plays key role in ecological disturbances by destroying natural predators of crop pests, plant growth-promoting bacteria and other soil micro/macro flora and fauna. These pesticides pollute environment very adversely, necessitating demand for safe organic farming to protect us from adverse effect of these pollutants. Organic waste composting is a technique which converts organic wastes into useful composts, which could be used as biofertilizer for sustainable agriculture growth. Conventional composting through microbes is a thermophilic process, in which many microbes are lost due to excess temperature emitted during the composting process. While vermicomposting is a mesophilic process, which conserves all microbes and earthworm associated with it to provide associated beneficial effect for degradation of organic matter by preserving the diverse community of all beneficial microflora. Vermicompost provides more biologically active and nutritive biofertilizers in soil as earthworms transform different organic waste material into useful vermicompost material by grinding, churning and digesting these substancesin association with microbes which is essential in biogeochemical processes [3]. Earthworms enhance the beneficial microbes and suppresses harmfulmicrobes to convert different infectious hospital wastes into risk-free materials [4].

Vermicomposts are rich in many nutrients including calcium, nitrates, phosphorus and soluble potassium, which are essentially required for plant growth [5]. Different plant growth hormoneslike gibberellins, auxinsand cytokinins are also present in vermicompost, which has microbial origin.

Nematodes are mostly small, colorless and microscopic organism remain under soil, fresh or marine water, plants or animals They act as parasite in different conditions, while very few has direct effect on human. Almost 50 percent nematodes are living in marine environment while about 25 percent of the nematode species live in soil and fresh water feeding on different decomposer organism including bacteria and fungi, many small invertebrates and organic waste Only 15 percent of the nematode species are parasitic in nature, infecting animals, ranging from small insects, many invertebrates and man. Only almost 10 percent nematode species are plant parasite in nature.

The nematodes which are parasitic on plant use plant tissues as their food through well developed spearing device like a hypodermic needle called style used to penetrate host cell membrane. Plant-parasitic nematodes release an enzyme into a host plant cell through stylet for partial digestion of cell content before entry into gut. Nematode causes injury to plants in two ways involving their feeding mechanism. Few nematodes are ectoparasitic which utilizes different plant tissues outside the plant for their food, while few nematodes are endoparasitic which utilize inner part of plant tissues as their food. Few nematodes are migratory known as foliar nematodes which utilizes the leaves and buds of ferns, chrysanthemums, strawberries and many other ornamentals as their food. Foliar nematodes cause death of buds, distortion of leaf and formation of dark-brown to yellow lesions between major veins of the leaves.

Management of plant-parasitic nematodes therefore is necessary and several means are adopted. Of which use of bio-chemicals have shown encouraging results and proved to be potential in suppressing the nematode population. Vermicompost plays an important role of soil fortification on growth characteristics, such as length, weight, root, shoot branches, number of leaves and metabolism of host plant against nematode infection. Vermicompost fortified plants showed increment in sugar, protein and lipid over untreated control. Increment of these metabolites treated plants and metabolically cope up the infection and promote excessive plant growth. Use of Vermicompost as fertilizer also helps in suppression of plant diseases and pest as it provides better nutrient availability and greater strength, immunity, and resistance against infection. Compost and vermicompost are effective in eliminating root-knot nematodes (*Meloidogyne incognita*) in tomato plants. Almost 40 species of bacteria and 22 species of fungi were identified in soil treated with vermicompost, of 40 bacterial species majority were found under the genus like *Azotobacter*, *Bacillus*, *Rhizobium*, *Pseudomonas*, *Beigerinicka* and *Enterobactor* and in fungal the genus such as *Aspergillus*, *Rhizopus*, *Pencillum*, *MucorCladosporium*, and *Fusarium* were commonly found [6]. Arancon et al. [7] had also observed a reduction in plant-parasitic nematodes following the application of vermicompost.

2. Vermicompost

2.1 Nutritional composition

The nutrient content obtained from vermicompost directly depends on the constituent of waste material where it feeds. It enhances levels of different material in casted soil than available mineral concentration due to microbial activity in its gut [8]. According to reports of Hand *et al*. [9] the earthworms enhance nitrogen mineralization in the soil, consequently resulting in more availability of nitrate in the soil. The vermicompost is also involved in reduction of organic carbon and carbon nitrogen ratio than in the normal composts. The combined earthworm and microorganism action lowered causes loss of different organic matter from the soil substrates as CO_2 introduces 20–43% of total organic carbon material in soil the completion of vermicomposting period. Vermicompost also contains all essential nutrients including nitrates, phosphate, exchangeable calcium and soluble potassium which are quickly absorbed by plants (Edwards, 1998; [10]). Also observed more micro and macro nutrients in the vermicompost which are rich in the earthworm casts.

2.1.1 C/N ratio

The carbon and nitrogen (C/N) ratio is most important parameter during composting process which clearly indicates about the decomposition rate. Plants are able to take mineral nitrogen in the form of nitrates, only when carbon and nitrogen ratio falls below 20 [11]. The proper ratio of carbon and nitrogen is therefore required for the proper plant growth. Earthworms cause reduction in carbon level thereby increasing the nitrogen content in fresh organic matter.

2.1.2 Nitrogen

Nitrogen is very essential constituent of all amino acids and protein. Deficiency of nitrogen directly decreases the growth of plants leading to chlorosis, stunted and slow growth. According to Hand *et al*. [9] mineralization with nitrogen was highly facilitated in earthworm presence and it leads to deposition of nitrate in the soil.

2.1.3 Phosphorus

Earthworms activity causes increase in total phosphorus concentration in soil in comparison to the food source available in soil. This clearly indicates that the vermicomposting causes increase in phosphorus level through the mineralization of phosphoric organic compounds [12, 13].

2.1.4 Iron (Fe)

Iron (Fe) is also an important element required for growth and productivity of all plants. Only very trace amount of iron is required in comparison to other minerals by plant like carbon, oxygen, hydrogen, nitrogen, phosphorus, sulphur and potassium for proper plant growth. The iron functions like a cofactor, as it has a catalytic site for many essential enzymes activity which are even required for chlorophyll synthesis.

2.1.5 Magnesium (Mg)

It is a important component used in formation of chlorophyll, which play vital role in photosynthesis. It is also required for carbohydrate metabolism and acts as enzyme activator in nucleic acid synthesis. Magnesium serves as a carrier of phosphate compound in plants and also supports uptake of many essential elements into plant. It enhances production of oils and fats through the translocation of carbohydrates.

2.1.6 Manganese (Mn)

Manganese (Mn) plays vital role in nitrogen assimilation by, as enzyme activator. It is very important constituent of chlorophyll. Low plant manganese usually causes leaves to turn yellow due to reduced chlorophyll content. Organic soils usually contain intermediate amounts of manganese.

2.1.7 Zinc (Zn)

Low presence of zinc leads to high yield of crops. Zinc efficiency has been reported in many enzymatic activities of plants [14]. Zinc utilization mechanism in plant tissue is most important mechanism of zinc in plant tissues. Heavy metal bioaccumulation study showed that increased duration of vermicompost concentration of Zn and Cu decreases soil [15].

2.2 Role of vermicompost in plant growth promotion

Wide variety of plant species grows effectively in vermicompost rich soil, including many horticultural crops like tomato, cauliflower etc. [16], aubergine [17], garlic, pepper [18], strawberry, green gram and sweet corn [19]. Vermicompost is also very much effective on enhance production of many medicinal plants rich in aromatic compounds [20], cereals such as rice and sorghum [21], fruit crops such as papaya and banana, and ornamentals like geranium [22], petunia, marigolds and poinsettia. Effect of vermicompost was also observed in forest trees including eucalyptus, acacia and pine tree [23]. Vermicompost are very beneficial and used as a partial or total substitute for chemical fertilizer in agriculture and artificial greenhouse potting media. Likewise, few studies show that water-extracts obtained from vermicompost, vermiwash were used as foliar sprays, which enhances growth of tomato plants [24], strawberries and sorghum. Vermicompost also stimulates seed germination in green gram and other plant species [25], tomato plants [26], pine trees and petunia. Vermicompost are used effectively for vegetative growth of leaf, stimulating growth of root and shoot [27]. These effects cause increase in root branching and leaf area and alterations in morphology of seedling plant [28]. Vermicompost stimulates flowering in plants, increasing flowers produced [29], and increase in fruit yield [30].

2.3 Bacterial diversity associated with earthworms

A variety of bacterial species have been reported associated with earthworms/vermicompost though the bacterial species varied with its isolation site including soil, intestine, and excrements. Almost 43 bacterial species were isolated from earthworm intestines and 25 obtained from fresh excrements of which, 9 were common. Among 40 bacteria species isolated from soil and intestine, 13 were shared species; 9 were gram-positive, and 6 Bacillus species were spore-forming. Comparison of soil and excrements bacteria revealed similarity of only 6 isolated species, of which three species were gram-positive and three species were gram-negative. *Brevundimonas diminuta* (α-Proteobacteria), *Kocuria palustris* (Actinobacteria) and D. acidovorans (β-Proteobacteria), were isolated from all three substrates. Comparison of bacteria isolated from the intestine of *Aporrectodea caliginosa*, *Lumbricus terrestris*, and *Eisenia fetida* earthwormsrevealed that the highest number of 43 bacterial taxa was isolated from *A. caliginosa* digestive tract; while from *L. terrestris* and *E. fetida*, 22 and 21 taxa were isolated respectively. Few members of bacteria were isolated from all earthworm species, which includes Bacteroidetes (classes Flavobacteria and Sphingobacteria), Actinobacteria, Proteobacteria (classes α-, β-, γ-) and Firmicutes (class Bacilli). Five bacterial species isolated from earthworm exhibited relatively low similarity between the sequenced 16S rRNA gene fragments (approx. 1490 nucleotides) and the genes of known bacterial taxa (93–97%), which includes Ochrobactrum sp. 341-2 (αProteobacteria), *Sphingobacterium* sp. 611-2 (Bacteroidetes), *Massilia* sp. 557-1 (β-Proteobacteria), *Leifsonia* sp. 555-1, and a Microbacteriaceae, isolate 521-1 (Actinobacteria).

Micromycetes were observed in digestive tracts of fasted earthworm species. The incubation temperature had no effect on the number of fungal CFU isolated from the intestines. Fungi isolated from the earthworms after 20 days of starvation, are *Bjerkandera adusta* and *Syspastospora parasitica* identified by light-colored sterile mycelia, as well as *Geotrichum candidum*, *Alternaria alternata*, *Acremonium murorum* (*A. murorum* var. *felina*), *A. versicolor*, *Aspergillus candidus*, *Rhizomucor racemosus*, *Mucor hiemalis*, *Cladosporium cladosporioides*, Fusarium (F. *oxysporum, Fusarium* sp.), and *Penicillium* spp.. The density of fungal colony in the air dry intestine was 103–104 CFU; this value is very close to the fungal populations density in soil mineral horizons. These fungi are most resistant to the conditions within earthworm digestive tract.

2.4 Role of vermicompost in nematode control

The application of vermicompost resulting in reduction of free-living nematodes populations owing to, its adverse effects on these nematodes. The management of plant-parasitic nematodes is very difficult in comparison to management of other insect pests and pathogens. The plant-parasitic nematode generally resides in soil and attacks the underground parts of plants. While cyst nematode management faces a unique challenge owing to hard protecting cyst wall protects egg of gravid females. Prevention is the most common economical control method, because once any plant is parasitized by nematode, it is essential to destroy host for killing worm effectively. At present chemical nematicide is commonly used in controlling different types of plant-parasitic nematodes in the soil [31]. Frequent treatment of soil with different chemical is dangerous and adversely affects soil organisms, environment, as well as animal and human health. Gabour *et al*. [32] observed inhibitory effect of vermicompost application on the populations of the plant-parasitic nematode *Rotylenchulus reniformis*. In addition to vermicompost, recent studies have shown that the application of vermicompost tea has the potential to control plant-parasitic nematodes. In this sense, Edwards et al. [33] studied a significant suppression in the number of galls caused by *Meloidogyne hapla* in tomato when the plants were subjected to aerated vermicompost tea. The effects of vermicompost are likely on nematodes due to the mortality of nematodes by the release of nematicidal substances such as hydrogen sulfate, ammonia, and nitrite produced [34]. promotion of the growth of nematode predatory fungi that attack their cysts [35]; favoring of rhizobacteria that produce toxic enzymes and toxins [36]; or indirectly by favoring populations of nematophagous microorganisms, bacteria, and fungi, which serve as food for predatory or omnivorous nematodes, or arthropods such as mites, which are selectively opposed to plant-parasitic nematodes [37].

3. Mechanisms that mediate nematode control

3.1 Crop rotation

It reduces many soil-borne diseases and improves soil for agriculture. Many nematodes can reproduce, grow and survive on selected plants and not able to grow on other crops and hence die with practice of crop rotation. Repeatedly growing of single crop in particular field will enable any organism to reproduce successfully and increase their number. While introduction of crops which does not support nematode growth will prevent reproduction and growth of nematode and allow natural mortality factors to act on these to reduce their numbers. Through the planned rotation of crop and sequential alteration of crop, it is possible to reduce excessive growth of all pests of all of the major agriculture crops. Hairy indigo would reduce numbers of sting and rootknot nematodes and can be planted as a summer crop in between other crops. Pangola digitgrass a common agriculture crop of West Indies and Florida, which control burrowing and root-knot nematodes in vegetable lands. Use of crop rotation usually provides multiple benefits including mineralization of soil as well as effective pest control in agriculture field.

3.2 Crop root destruction

Through destruction of root whole pest colony which resides on root are destroyed, and leads to decline in number of nematodes through increased mortality. This can stop nematode reproduction and should encourage their decline through normal mortality. Crop root systems are reservoir for many soil-borne diseases and nematodes. These small insects and nematodes can multiply on root system of crop whenever it will remain alive. Almost 10 folds increase in nematode concentration were observed when soil temperature were high. Even when soil temperatures are declining, at least one additional generation of nematode were found. It was very good practice in nematode management to destroy root of previous crop to prevent growth and reproduction of nematode.

3.3 Flooding

Flooding the agriculture land was also used to reduce numbers of soil infesting pests including plant-parasitic nematode. It is done through regular maintenance of high water level in field for many weeks in controlled manner. This high water level is maintained in field for two or three weeks followed by drying the soil and flooding again for two to three weeks is more effective way of controlling plant-parasitic root nematode. Flooding generally kills root nematodes by inhibition of nematode parasite with interaction to host plants for longer period.

3.4 Fallowing

It is a process in which a field is left without any type of vegetation and plants for longer period; it leads to starvation of nematodes or other pests in absence of vegetation. Most soil pests and nematodes were decreased due to lack of food in the form of host plants. The field must be regularly cultivated to prevent growth of different weeds and it leads to proper cycling of drying and heating to different layers of soil.

3.5 Plant resistance

Many plants are resistant to different types of pests, And their use in agriculture field is most effective and less expensive way of pest control strategy. But this method requires detailed knowledge on various resistant plants and pest categories and situation which does not support pest survival, but most of nematode resistant crop has resistant for only few nematode species and it would not be completely resistant to all species of nematode.

3.6 Biological control

Many biological agents like bacteria and fungi are nature well known enemies of nematodes. These do not support growth of nematode species when concentration of these bacteria and fungi are high. Many scientific studies on nematode are able to reduce nematode population with the help of these bacteria and fungi under laboratory conditions. But at field levels this is emerging field of research and success rate are not very high. However, the use of organic materials to the soil has been found reported to increase the availability of food for fungivorous and bacteriophage nematodes, increasing the competition between them with other groups.

4. Nematode associated with agricultural crops

Nematode species varies greatly in different countries. Few nematode species are cosmopolitan, likespecies of *Meloidogyne* while many are geographically restricted to particular region e.g. different species of *Heterodera, Globodera,* etc. *Nacobbus*species are highly specific attacking only carrots. Some crops are infected with very few species of nematode pests while others are infected with wide range of nematode species. Crop like rice, maize and sugar cane are infected with variety of plant-parasitic nematodes. Common plant-parasitic nematodes associated with different agricultural crops are: *Meloidogyne, Heterodera, Globodera, Pratylenchus, Radopholus, Rotylenchulus, Tylenchorhynchus, Xiphinema, Longidorus, Paralongidorus, Aphelechoides, Ditylenchus* etc.

5. Nematode management through microbial biogents

Nematode mainly attack underground parts of plant, due to which management of nematode are very difficult in comparison to other plant parasites [38]. At present synthetic nematicides are frequently used for management of plant-parasitic nematodes [39]. Although, nematicides are very efficient and fast acting, but are relatively unaffordable to many small scale farmers.

Application of organic amendments is one of the best practised alternative strategies for the management of plant-parasitic nematodes in the soil [40]. Organic amendments have shown beneficial effect on soil physical conditions, soil nutrients, and soil biological activity, thus improving plant health and reducing colonies of plant-parasitic nematode. [41]. Integrated pest management (IPM) uses different strategies for the management of plant-parasitic nematode but the biological control would be the most effective and economical way of nematode management. Different groups of beneficial bacteria have been utilized for the management of plant-parasitic nematode in soil. Various fungi such as *Aspergillus*, *Paecilomyces*, *Trichoderma*, *Verticillium*, *Pochonia*, *Fusarium* and *Penicillium* have been reported to cause juvenile mortality and egg inhibition of nematodes. An increase in nematicidal potential of microorganisms were observed when such bacteria, fungi or other biocontrol agents are integrated with either organic amendments or nematicides for integrated control of nematodes [42, 43].

6. Ecological and economical importance of biomanagement

The nematodes can survive in different environments including aquatic (such as fresh water, estuarine and marine water), terrestrial (as free living in the soil) and parasitic (either endoparasites and ectoparasites of animals and plants). Pokharel, and Larsen [44] and Pokharel., *et al*. [45], reported that soil nematodes are very important in protecting the organic nature of soil, Phytoparasitic nematodes on feed tissue of plants and reduce the growth and productivity of infected plants. Soil nematodes assist colonization of microbial substrates and nutrients mineralization in the soil. Metabolism in nematodes produce important nutrients like nitrogen and vitamins which speed up bacterial growth in the soil. Many nematodes feed on bacteria, fungi and protozoa within soil and acts like predatory or omnivorous nematodes it would improve cycling of nutrients and causes slow release of nutrients into soil. The free-living nematode in soil enhances mineralization of nutrient in soil. These nematode groups also feed different plant pathogen and few soil microbes including plant pathogens such as bacteria and fungi. Free-living nematodes can protect system crop by protecting nature of soil. The nematodes which attack insect pests are useful biological insecticide [46].

According to data of the American Phytopathological Society, nematodes have great economic benefits of both harmful and useful effect, most plant nematodes has a sharp needle-like structure found in mouth part called stylet. They is cause more than 15percent loss of crops per annum world-wide, equal to almost US$78 billion. Majority of plant feeder nematodes found in the soil, feed on plants and reduce water and nutrient absorbed by the plants root, reducing their drought resistance ability. Some other nematodes transmit disease causing organisms like viruses to plants while feeding. Large number of nematode species cause decomposition and recycling of nutrient by release of relevant nutrients for the plant growth.

From more than 4000 described plant-parasitic species of nematodes, only some cause economic losses in crops. Some of the major genera of phytoparasitic species of nematodes causing crop losses are *Xiphinema, Rotylenchulus, Pratylenchus, Meloidogyne, Hoplolaimus* and *Heterodera* [47]. The majority of soil nematodes are present in the rhizosphere of plant root area in the soil surrounding the root of plant where microbiological activity is exceptionally high.

7. Enrichment of beneficial microorganisms in vermicompost

7.1 Enrichment of vermicompost with bacteria

Earthworm's gut microflora has high ability to increase plant nutrient availability. Earthworms highly influence the soil dynamics and chemical processes, by adding its litter and affecting the soil micro-flora activity [8]. Earthworms and microorganisms interaction seem to be very complex. Earthworms excretes plant growth-promoting substances and making soil fertile. Pseudomonas oxalaticus an oxalate-degrading bacterium was isolated from intestine of different species of earthworm and *Streptomyces lipmanii*from actinomycetes group was identified in the gut of *Eisenia lucens*. Scanning electron micrographs showed presence of endogenous microflora in guts of earthworms, *L. terrestris* and *Octolasion cyaneum*. Gut of *E. foetida* contained various anaerobic N2-fixing bacteria such as C. *Beijerinckii, Clostridium butyricum* and *C. paraputrificum*.

7.2 Enrichment of vermicompost with fungi

A total of 194 fungal entities comprising 117 mitosporic fungi, 45 ascomycetes, 15 zygomycetes, 14 SM morphotypes and three basidiomycete morphotypes were reported from the vermicompost. Mitosporic fungi including the ascomycetes in their anamorphic state are the most dominat. The thermotolerant fungus, Scedosporium state of *Pseudallescheria boydii* also display a significantly high load in vermicompost, However *Penecillium* and *Aspergillus* showed highest load in vermicompost.

8. Enrichment of vermicompost and agriculture benefits

Vermicomposting is biotransforming process, stabilizing waste organic materials into humus by joint activity of microorganism and earthworms. Earthworms excrete casts which are partially digested waste materials, commonly known as castings or vermicast, and are homogeneous in composition of minerals than the source waste material. Vermicompost has very least levels of contaminants, and contains increased amount of minerals, plant hormones, symbiotic microbes and organic acids including fulvic and humic acids. Vermicomposting is a process of compost production by breeding, growing and maintaining earthworms population in soil. The earthworms cause biooxidation of waste by relentless turning, aeration, and fragmentation resulting in formation of homogeneous and stabilized humus in soil, which is useful for plant thus used as manure in agriculture field. Vermicomposting is very effective for maintenance of biodegradable household waste and Municipal Solid Waste at many places. Aerobically incubated extract of compost are now in high demand commercially for agriculture work. As being are rich in carbohydrate and a protein source. It is known as 'compost teas' which is microbially very rich. The casting by earthworms consists of many nutrient including Nitrogen, Phosphorus, Potassium, Calcium and Magnisium.

9. Conservation of microbial biogents

9.1 Bacteria

Bacteria are generally found in very diverse habitat including marine water, fresh water, soil and compost piles. Many bacteria are found in gastrointestinal tract of animal system. Few bacteria also reside in oxygen deficient conditions like in flooded soil. While most bacteria required well aerated soil. Many of bacteria grow and reproduce very rapidly in acidic and neutral soil conditions. Bacteria are first decomposer found in soil which initiates process of decomposition of different material in it. Through the process of decomposition bacteria makes different minerals available to plants. Phosphorus is also dissolved by bacteria and plants can utilize this dissolved phosphorus easily for their growth. Nitrogen fixing bacteria fixes nitrogen in soil for plants. Plants require large amount of nitrogen in agriculture soil for proper growth. It is well known fact that nitrogen present in atmosphere is neither consumed by animals nor plants for their nutrition and growth. Few nitrogen fixing bacteria has ability to convert these nitrogen gas into nitrate which is easily absorbed by plants. Plants use this nitrogen compound to form different types ofamino acids and proteins. This process of formation of nitrate compound through free nitrogen is called *nitrogen fixation*. Nitrogen-fixing bacteria generally reside in root nodules of plant to form mutually beneficial symbiotic associations with plants. Rhizobium bacteria reside in root nodule of different leguminous plant and fixes nitrogen present in air effectively while these bacteria uses sugars of plants for their energy source. Bacteria in alfalfa field can fix many hundreds pounds nitrogen per acre per year.

Pea plant fixes very less amount of nitrogen in field, it accounts for only 30 to 50 pounds per acre. Large molecules of lignin were broken down into very smaller in size through actinomycetes. Lignin is a complex and large molecule found in plant tissue, it protect cellulose from decomposition, bacteria acts on it and degrade it in to simpler form during the process of decomposition. Earthworms can also facilitate the dispersion of microorganisms by the excretion of their spores in the coprolites. However, the dispersion of nematophagous fungi by earthworms might be responsible for the reduction of the nematode populations in the substrates. The mechanisms by which vermicomposts and their aqueous extracts suppress plant-parasitic nematodes after application to soil, are speculative. Larger predator–prey populations can also contribute to lower densities of plant-parasitic nematodes in vermicompost-treated soils [48]. Vermicomposts can increase the numbers of predatory or omnivorous nematodes or arthropods such as mites that selectively prey on plant-parasitic nematodes [48, 49]. Vermicomposts can promote the growth of nematode-trapping fungi and fungi that attack nematode cysts and may thereby influence the populations of plant-parasitic nematodes [35].

9.2 Fungi

Fungi are also important constituent of plant microorganism. Many fungi produce a number of antibiotics. Fungi also initiate the decomposition of waste as well as fresh organic residues. They act on surface of material, making it soft and available for other microorganism for initiating the decomposition of organic material. Decomposition of lignin also require fungal activity followed by bacterial decomposition process.

9.3 Algae

Many algae, like crop plants, make sugars with the use of sunlight and carbon dioxide, which is used for energy need and formation of other complex molecules. Flooded soil and rice paddy field are rich in many species of algae. These algae grow on surface of wet soil and form mutually beneficial relationship with other organism for enhancing nitrification and mineralization process in soil. It also shows formation of lichens in agriculture field.

9.4 Protozoa

Different species of protozoa use a variety of means for increased productivity of soil. Protozoan's feed on bacteria, fungi and other protozoa and waste materials. Protozoa acts like secondary consumers of organic materials. Protozoa consuming nitrogen rich organisms and excreting wastes rich in nitrogen element this is believed to be responsible for mineralizing much of the nitrogen in agricultural soils.

Author details

Sunil Kumar[1*], Ranjit Kumar[1] and Pankaj Sood[2]

1 Department of Animal Science, School of Life Science, Central University of Himachal Pradesh, Dharamshala, H.P., India

2 CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India

*Address all correspondence to: sunilibes@gmail.com

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